NOTES ON THE LARVAL FEEDING HABITS AND THE LIFE HISTORY OF EUMERUS TUBERCULATUS RONDANI.[1]

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Introduction

In 1929 investigations on the lesser bulb flies of the genus Eumerus were initiated at Babylon, N. Y., on Long Island.[2] Studies were especially directed toward the feeding habits of the larvae, for the purpose of determining whether they are primary pests or scavengers, but some notes on life history were also made.

Previous to 1928 it was generally considered that the lesser bulb fly was only one species. The work of Hodson, Cole, Latta, and others indicated that this group actually consisted of three species, *E. tuberculatus* Rondani, *E. strigatus* Fallén, and *E. narcissi* Smith, Only a few specimens of *E. strigatus* and none of *E. narcissi* were taken on Long Island,[3] *E. tuberculatus* being by far the most common. Therefore, the investigations here were confined chiefly to this species. Although the data thus far obtained do not clear up the status of *E. tuberculatus,* it is believed that they do throw further light on the subject. This work was done during July, August, and September, 1929.

Oviposition in Cages

In the first attempts to obtain eggs, several hundred flies were placed in each of several Riley cages about 36 inches high and 18 inches square and the cages were kept in the sun. The flies were fed daily with undiluted extracted honey. Bulbs that had been discarded at the packing sheds were placed in the cages and examined daily. The flies were never seen on the bulbs and no eggs were found.

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[1] These investigations were conducted under the general direction of Dr. C. A. Weigel, with the assistance of Dorothy Martin, field assistant.

[2] Work along the same lines was already in progress in California and at Sumner, Wash.

[3] The determinations of the several hundred Eumerus specimens used in this work are based on comparisons with material and furnished by Dr. F. R. Cole.

Flies confined in a stock cage 6 feet high and 5 feet square remained on the sides near or at the top, and never near the heavily infested and decaying bulbs covering the floor of the cage. Mating was observed, but no eggs were ever found in this cage.

When the flies failed to oviposit in the Riley and stock cages, they were placed in small cylindrical ones. These cages were of 16-mesh screen, 10 inches long and 5 inches in diameter, and closed at the ends with cloth sleeves. From 30 to 60 flies from a few hours to two days old were released in each cage. Every day the dead flies were removed and replaced by newly emerged ones. Only a small percentage of the flies laid eggs. These eggs, supplemented by some collected in the field, were used for the various studies.

Eggs found in the cages were laid singly or in clusters up to 40. They were usually out of sight either at the neck under the dead skin covering the bulbs or in the crevices in the cork tissue at the basal end. These observations are in agreement with those made by Broadbent.[4] The few eggs found on completely decayed bulbs were usually on some dry spot; those laid upon very moist decayed tissue became discolored and eventually collapsed.

Field Observations on Oviposition

Field observations of egg laying made on Long Island confirmed those made by Hodson[5] in England. As harvest time approaches, the drying leaves shrink and fold, leaving holes in the soil beside them. Also at this time cracks are formed by the drying of the soil, such crevices following the ridge of the bulb row, often exposing some of the basal portion of the leaf. Flies were frequently observed entering such holes, presumably in search of places in which to oviposit. Many Eumerus eggs were collected in the folds of the dried leaves or in the bits of soil that happened to cling to them. Most of the eggs were found 1 or 2 inches beneath the surface of the soil, although occasionally they were found upon the surface. This is in agreement with the foregoing observations in the cages, where the eggs were generally laid in dry or slightly moist places.

According to Wilcox,[6] *E. strigatus* in Oregon deposits the ma-

[4] Broadbent, B. M. 1925. Notes on the life history of the lesser bulb fly, *Eumerus strigatus* Fallén. Jour. Encon. Ent. 18: 141–143.

[5] Hodson, W. E. H. 1927. The bionomics of the lesser bulb flies, *Emuerus strigatus* Fln., and *Eumerus tuberculatus* Rond., in southwest England. Bul. Ent. Res. 17:373–384, illus.

[6] Wilcox, Joseph. 1926. The lesser bulb fly *Eumerus strigatus*

jority of its eggs about one-quarter inch beneath the soil. "Some eggs are deposited directly on the surface, while others have been found three inches deep in the ground * * *."

While watching for oviposition upon freshly dug bulbs in the field, the author observed a female of *E. tuberculatus* laying eggs in the soil. As soon as the fly settled on a clod, she extruded her ovipositor and began to search for suitable places in which to deposit eggs. After inserting and withdrawing the ovipositor from a number of tiny holes in the clod, she finally selected one and remained with her ovipositor thrust in the hole for about a minute. From the muscular contractions of the abdomen it was evident that eggs were being laid. Later examination disclosed 30 eggs side by side in the tiny soil pocket. The female then made examinations of another clod and laid three more eggs. Other females were observed to oviposit in the same manner. The clods in which the flies were laying eggs were several feet from the nearest bulb.

The behavior of the female usually ovipositing in the soil or on the leaves of the bulb rather than directly upon it, may explain why so few eggs were obtained under artificial conditions. These habits also suggest that the female makes no distinction as to location or condition of the bulb.

Incubation

Eggs produced under cage conditions and held for incubation were removed with a bit of bulb and placed in test-tubes, which were then stoppered with cotton. Eggs laid in the field were allowed to remain upon the leaves. Too dry conditions in the test-tube made it difficult for the larvae to escape from the egg and also caused them to desiccate rapidly after hatching. This was avoided by keeping the walls slightly moist; too much moisture increased the mortality at the time of hatching. The larvae were removed with a camel's-hair brush.

Although the data were gathered within a period of nine weeks, the temperature varied sufficiently to make it possible to measure its effect upon the length of the relatively short incubation period. The mean temperatures were calculated from hygrothermograph records by means of a planimeter and then the mean length of the

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Fallén in Oregon. Jour. Econ. Ent. 19: 762–772. For these studies Wilcox states that he retained only the name, *E. strigatus*. Curran determined specimens for him as *E. strigatus* and *E. tuberculatus*. There is even a possibility of *E. narcissi* Smith being present in his complex of species, since this insect occurs on the Pacific slope as far north as Oregon.

incubation period was determined at the different temperatures. The numerical records[7] are summarized as follows:

Forty-two eggs incubated at a mean temperature of 64.7° F.; mean length of stage 5.1 ± 0.20 days; standard deviation 1.9 days; minimum length of stage 2 days; maximum length of stage 9 days.

One hundred forty-four eggs incubated at a mean temperature of 67.4° F; mean length of stage 4.4 ± 0.06 days; standard deviation 1.2 days; minimum length of stage 3 days; maximum length of stage 7 days.

One hundred eggs incubated at a mean temperature of 70.2° F.; mean length of stage 4.1 ± 0.07 days; standard deviation 1.1 days; minimum length of stage 2 days; maximum length of stage 8 days.

Twenty-two eggs incubated at a mean temperature of 72.1° F.; mean length of stage 4.0 ± 0.14 days; standard deviation 1.0 day; minimum length of stage 4 days; maximum length of stage 6 days.

The mean lengths of the egg periods have been plotted against the corresponding mean temperatures in Pl. II. The diameters of the circles in Pl. II vary in size in proportion to the square root of the number of cases. Of course, as one would expect at these temperatures, the curve shows that the length of the egg stage decreases with rise in temperature.

Feeding Habits of the Larvae and Effect on Mortality

Since Hodson[8] has already published field observations of larval habits which are in agreement with the notes from Long Island, excerpts are taken from his comments: Larvae "hatching from eggs laid on the soil make no attempt to burrow through it, but travel * * * towards the cavity surrounding the adjacent bulb-neck * * *. Eventually all * * * arrive * * * where the dried foliage meets the still living neck of the bulb * * * undoubtedly attracted by the presence of a certain amount of damp and rotting tissue at the actual point of union. Many larvae commence to feed * * * and gradually enlarge the rotted area * * *." He comments upon the manner of entrance into the base as follows: "Such a point of entry is occasionally available in form of a cavity left where a root has died away, or a split where an offset is breaking away from the main bulb. * * * entry may be made at any suitably damaged point in the bulb."

[7] Sixty-four eggs, recorded as laid on August 27, hatched in two days at a mean temperature of 67.5° F. These data differed so widely from the remaining data that they are believed to have been entered incorrectly and accordingly are not included in the summary.

[8] Hodson, W. E. H. *Loc. cit.*

In the studies on Long Island with dormant bulbs full-grown Eumerus larvae were always found in decayed tissue. This suggests the possibility that decayed tissue is necessary for the development of the larvae. Close observations in the laboratory of 335 newly hatched larvae caged upon bulbs under a number of different conditions give added weight to this opinion.

It should be remembered, however, that these observations were made on dormant bulbs, as the experiments were conducted in August and September. At this time of the year the bulbs are full of stored starch and very hard. No doubt the condition of the soil surrounding undug bulbs or of the growing bulbs before the tops die back would influence the results. For this reason no conclusions can be drawn as to how the larvae will act in the spring when on the growing bulbs.

Bone rings one-eighth inch thick and an inch in diameter (such as are used for fancy needlework) fastened to the bulb with paraffin made convenient cages for microscopic studies of the larval habits and of the condition of the bulb tissue. With a pair of hot tweezers the wax was spread evenly around the inside and outside of the ring where it touched the bulb. A cover glass fastened with paraffin served as a cover. The cage could be easily opened by pushing a needle between the glass and the bone ring. The outer dry skin covering the bulb was removed before setting the cage upon the epidermis. Two or three drops of water were placed daily in most cages to delay desiccation of the larvae. Dormant bulbs, mostly of the Emperor and King Alfred varieties, were used for food.

Experiment A

Fifty-seven larvae were sealed in three cages on spots of apparently healthy bulbs where the epidermis had been broken and the tissue bruised to a pulp. Twenty-six of the larvae died in 4 days, 12 in 5 days, and 15 in 13 days; 4 disappeared. The bruised tissue did not discolor or decay in any of the cages.

Experiment B

One hundred and nineteen larvae were placed in seven cages upon unbruised epidermis of healthy bulbs. They were placed on the sides, neck, and base of the bulbs, the base being cut so as to remove the tough cork and expose the tissue. They rasped the epidermis continually and shortly the injured cells were marked in block patterns by a light brown discoloration. Only the cells forming the outside surface of the bulb seemed to be injured, discoloration remaining confined to the rasped areas. Larvae placed in

the neck of the bulb crawled between the storage leaves. All the larvae in this set of experiments gradually desiccated and died. The fact that none entered the tissue indicates that these larvae were unable to break the tough epidermis of dormant bulbs with their mouth parts, and that the epidermis was probably not affected by salivary juices. Hodson has suggested that "Liquefaction [of the bulb] is apparently aided by strong salivary juices * * *."

Experiment C

Sixteen larvae were confined in a cage placed upon unbroken epidermis over an area of partly decayed and partly healthy tissue. Some particles of débris from a decayed bulb upon which the ring had previously been placed clung to it. The larvae immediately congregated upon the ring. They were moved a number of times to the epidermis, but each time they returned to feed upon the decayed particles. Most of the débris had been eaten by the fifth day, at which time the larvae attempted to enter the decayed tissue of the bulb. This area was sliced off after they had been on the epidermis a week. The larvae were able to develop in the soft, decayed portion, and eventually adults emerged.

Experiment D

(1) Twenty larvae were confined upon a flat area made by slicing off a piece of the bulb. The water placed daily in the cage did not seem to soften the tissue except in two spots. No decay or discoloration of the tissue appeared. The larvae moved restlessly back and forth between the bottom of the cage and the cover slip. They were able to scrape the tissue only in the softened spots to the depth of a millimeter. Sixteen larvae were unable to develop and died after being in the cage 16 days. At this time a similar flat area was made on a decayed bulb and the four remaining larvae were transferred to it. They grew from 1.25 to 8 mm. in length in 11 days. At this time the studies had to be discontinued.

(2) This experiment was similar to (1). Sixteen larvae attempted to feed upon a sliced-off area of a healthy bulb, but were not able to develop. They died in a week.

(3) About a half inch of the base of a healthy bulb was sliced off and a cage mounted upon the flat surface. The 17 larvae placed in this cage attempted to feed, but without success. They died in a week's time.

Experiment E

The larvae were confined upon the unbruised epidermis of bulbs in the advanced stages of decay, two on the side of one bulb and

four at the side of the base of another. In each case the dead, dry skin was removed. The larvae rasped the epidermis but were not able to break it. For a time the two on the side increased in size, but they did not appear healthy and they died before reaching maturity.

Experiment F

(1) Twenty-six larvae were caged upon healthy, bruised tissue. The bulbs for two cages were soaked 10 days, making the tissue much softer than normal for dormant bulbs. The larvae immediately began cutting channels, their efforts being confined between the epidermal walls of the storage leaves. The tissue cut from the bulb discolored and decayed several days after the larvae had been confined in the cage. As soon as decay appeared, the larvae began to develop rapidly.

When the larvae began to pupate, the two bulbs were opened. The only decayed tissue present in the two cages was that which had been cut off the bulb by the larvae. The surface of the hole which they had cut in the bulb was pitted and very uneven, and the hole was discolored only a few cells deep. The tissue beyond the discolored cells was unaffected by decay. The larvae had been able to cut healthy tissue, but apparently were not able to assimilate it until decay had appeared.

(2) The bulb used for the third cage was not soaked; however, the tissue began to decay shortly after 10 larvae had been placed upon it. Decay did not spread much beyond the feeding limits of the larvae. They reached the pupal stage.

Experiment G

Sixty-one larvae were confined in three cages upon the broken epidermis of decayed bulbs. They immediately burrowed into the tissue and began feeding. Several of the larvae pupated while the rest were in various stages of development, when the cages had to be abandoned.

Discussion of Results

The results of these experiments are shown in Pl. III. From these data it appears that *Eumerus tuberculatus* larvae are able to cut healthy bulb tissue only when they have a suitable entrance through the epidermis and when the tissue is soft, as it probably becomes under growing conditions. That there is a tendency for the larvae to develop as scavengers is shown by the following facts:

(1) When placed on healthy tissue the larvae did not begin to develop until it decayed; (2) when on decayed tissue they began to develop immediately; (3) mature larvae were always found in decayed bulbs.

The data of Hodson[9] give an idea of the ability of this species to enter healthy bulbs in the soil. For example, in a series of three experiments he found that 19 out of 72 healthy bulbs were attacked while 41 out of 72 decayed bulbs were entered. Thus, slightly more than twice (2.1) as many larvae were able to enter diseased bulbs as were able to enter healthy bulbs.

The larvae in a number of cages were observed to rasp the wax, which was softer than bulb tissue. Each rasped spot was marked by a fine striation which could be seen with the microscope. The wax often became discolored with bits of carbon from the match used to melt it. After the larvae had fed on the discolored wax, their alimentary canals were clearly outlined by the carbon particles through the transparent walls of their bodies.

Shellac was painted over the paraffin of several cages. Water caused it to become quite soft. The larvae were observed rasping upon it rather than upon the firm bulb tissue.

Length of the Larval Period

The length of the larval period seems to depend, in part at least, upon whether the larvae begin feeding in healthy or in decayed tissue. Under the former conditions the mean developmental period of seventeen larvae was 27.4 ± 0.55 days at a mean temperature of 72.5° F. Thirty-six larvae reared at the same time in decayed tissue completed their development in 22.1 ± 0.25 days. The difference between the two groups is 5.3 ± 0.6 days.

The Pupal Stage

The pupation habits of the flies on Long Island were about the same as described by Hodson[10] and by Wilcox[11] for the complex of species he called *E. strigatus*. In the field the pupae were found in the soil near the surface in close proximity to the bulbs or between the bulb leaves.

The data upon the effect of temperature upon the pupal stage

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[9] Hodson, W. E. H. *Loc. cit.*
[10] Hodson, W. E. H. *Loc. cit.*
[11] Wilcox, Joseph. *Loc. cit.*

were obtained in the same way as those of the egg stage and may be summarized as follows:

Twelve pupae developed at a mean temperature of 65.8° F.; mean length of stage 14 days.

Twelve pupae developed at a mean temperature of 65.8° F.; mean length of stage 12.9 ± 0.11 days; standard deviation 0.6 days; minimum length of stage 11 days; maximum length of stage 13 days.

Fifty-four pupae developed at a mean temperature of 69.0° F.; mean length of stage 11.9 ± 0.10 days; standard deviation 1.1 days; minimum length of stage 8 days; maximum length of stage 14 days.

One hundred forty pupae developed at a mean temperature of 70.3° F.; mean length of stage 11.0 ± 0.03 days; standard deviation 0.6 days; minimum length of stage 9 days; maximum length of stage 13 days.

These data are shown graphically in Pl. II. In this figure the steeper slope of the curve for the pupal stage seemingly indicates that temperature accelerates the development of the pupal stage more rapidly than the egg stage. If, however, instead of using the absolute lengths as dependent variables, the logarithms of the mean lengths of the egg and pupal periods are used, the relative effect of temperature upon development is clearly seen. The logarithm curves, which eliminated the effect of the dissimilar lengths of the stages, have nearly the same slopes, demonstrating that temperature had approximately the same effect upon the egg and pupal stages. The length of the pupal stage of the females was the same as that of the males.

Emergence

Emergence took place between 8 a. m. and 12 m., the peak occurring between 9 and 10 a. m. A few stragglers appeared in the afternoon. Broadbent[12] states that the species she had usually emerged at night. She has explained to the author that "night" covered a period between 4.30 p. m. and 8 a. m. Her unpublished notes made at Washington, D. C., in 1926 show emergence beginning at 5 a. m. and continuing throughout the morning. The peak appears a little earlier than in the data taken at Long Island. This might be explained by differences of light intensity. At Washington, D. C., the pupae were held in an outdoor, screened cage where they were exposed to more intense light than the pupae on Long

[12] Broadbent, B. M. *Loc. cit.*

Island, which were held in a room where little direct sunlight entered.

At the time of Miss Broadbent's studies the taxanomic status of *E. strigatus* and *E. tuberculatus* had not been established. Since *E. tuberculatus* is the most common species, probably most of the flies she had were *E. tuberculatus*.

Summary

Eumerus tuberculatus Rondani laid its eggs in the soil near the bulb or upon the leaves of the bulb just beneath the surface of the soil, usually in dry or slightly moist places.

Newly hatched larvae were not able to cut through the unbroken epidermis of either healthy or decayed bulbs. They were, however, able to enter dormant bulb tissue after it was soaked and broken. Decayed tissue seemed to be preferred by the larvae and is probably necessary for their development.

The developmental period for larvae in decayed tissue was 5.3 ± 0.6 days shorter than for larvae beginning their development in healthy tissue which later decayed. Apparently not much development took place until the bulb tissue began to decay.

Temperature had about the same effect upon the length of the egg and of the pupal stages. The length of the pupal period was the same for both sexes.

The peak of emergence appeared to be during the morning hours.

Explanation of Plates.

Pl. II. The effect of temperature upon the length of the egg and pupal stages.

Pl. III. Summary of the results of the larval feeding experiments.

Dorcus brevis Say in Alabama.—This rare, much disputed, but abundantly distinct species was first discovered in the State at Chicasaw, Mobile Co., in June, 1924, a female in the soil under an old *Magnolia grandiflora*.

Several years of hard work in the same locality failed to bring to light another specimen until June, 1929, when I took a male at sap on the base of an oak; friend Engelhardt was along that day, and he usually brings good luck as well as good cheer.

In May this year another male on the same tree and spot, and in June two more males were found under small rotten beech logs near lock 14 on the Warrior River, Tuscaloosa, Co.—H. P. Löding, Mobile, Ala.